Strategies to Improve Economic Efficiency of the Dairy

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■ Take Home Messages

‣ An opportunity to increase dairy farm economic efficiency exists by considering additional nutritional grouping for lactating cows

‣ Nutritional grouping that supports herd diets closer to cow's requirements saves feed costs and increases herd income over feed costs

‣ Gains on income over feed costs with additional nutritional grouping far exceeds possible additional expenses of management, labor, or machinery and potential milk losses due to cows' social interaction at regroupings

‣ Additional benefits of nutritional grouping include decreased environmental concerns because of tighter nutrient balances and improved herd health because of fewer over conditioned cows

■ Introduction

Grouping cows is a common practice farmers use to manage their herd more efficiently. Farmers use this strategy to separate far-off, close-up, sick, fresh, and pregnant cows. Grouping addresses cows' specific needs. However, grouping lactating cows for nutritional purposes and providing groups with more precise diets has not been adopted as widely as it could be, despite the fact that many studies demonstrate its economic benefits (McGilliard et al., 1983; St-Pierre and Thraen, 1999; Cabrera et al., 2012). Reasons of farmers not favoring nutritional grouping can be attributed to farm physical limitations (such as machinery and facilities), labor cost, difficulty in managing multiple diets, and the presumption that milk production will be largely depressed due to pen or group changes.

Total mixed rations (TMR) have become an industry standard and a large number of dairy farms are using just one TMR for all lactating cows. Applying

just one TMR to all lactating cows results in more over conditioned cows and higher nutrient excretion. These alone could be enough reasons to consider additional nutritional grouping as a valid dairy herd management option.

Moreover, adopting additional nutritional feeding strategies could substantially decrease feed costs that represent the single largest expense for dairy production and determine largely herd profitability. Additional nutritional grouping strategies will therefore increase the herd income over feed costs and contribute largely to improved profitability and economic efficiency.

This simulation study aims to evaluate and demonstrate the economic and environmental benefits of nutritional grouping strategies on lactating dairy cattle. Furthermore, this paper also includes a description of a simplified online decision support tool that could be used to evaluate farm-specific *grouping strategies for feeding lactating dairy cattle.*

■ Materials and Methods

Simulation Framework

A model was developed to simulate each individual cow of a herd to study different nutritional grouping strategies. The model mimicked cows' life events within reproductive cycles. An individual cow reproductive cycle started by calving and ended by involuntary culling, death, or entering a next lactation. The model used the next event scheduling approach (De Vries, 2001). These events included: involuntary culling (and reasons for culling), death, pregnancy, abortion, dry-off, and parturition. For each event, a two-step approach was followed: 1) determining the binary outcome of the event (it happens or not) and if it happens 2) the day of the occurrence.

Hence, the first step consisted on generating a random value, which was used to determine the outcome of an event by comparing it to a testing threshold. For example, if the probability of being culled in the first lactation was 17%, a value < 17% indicated that the cow would be culled. The second step consisted of generating another random value to schedule the day the event would occur. For example, if the outcome in the first step was culling, the second step determined the days in milk (DIM) on which the culling would occur. This process was similar for all other events.

After scheduling all the events, the status of every cow in the herd was updated on a daily basis according to scheduled events. For example, if a cow was scheduled to be pregnant at 90 DIM, then the cow information was updated as pregnant when 90 DIM. When the event involved culling or mortality, replacement was assumed to occur the next day to maintain the herd size constant (Cabrera, 2012). Replacement occurred with a springer heifer at the time of first calving.

Input Data

The model starts with actual data from a commercial dairy herd. It first reads an input file containing cow-level information of a herd. Then, it performs a projection of each cow and of the whole herd over a year. Parameters included in the input file are: cow id, parity, DIM, days in pregnancy, fat percentage, protein percentage, 305 mature equivalent (ME305 in kg/cow), body weight (if available), and predicted producing ability (PPA) -producing ability of cow in future lactation- (if available).

Cow attributes. The following sections describe the methods used for calculating the attributes of an individual cow on a given lactation and DIM. Some of these attributes were held constant for the lifetime of cow (e.g., PPA), and some varied based on lactation and DIM (e.g., lactation curves).

Milk, fat and protein production. Cows in the herd were categorized based on their PPA or, in its absence, on their milk mature equivalents at 305 days (ME305). Therefore, every cow was classified based on their future capability of production relatively to this reference by scaling up or down their production. Then, the Wood function (Wood, 1967) was used to calculate daily milk production of a cow.

Involuntary culling and death. Data from Pinedo et al. (2010) were used to determine risks of culling and death and also the reasons for culling. Non-pregnant cows with DIM > 300 were marked as do-not-breed and they were culled (reproductive failure) whenever their milk production reached < 24 kg/d (Kalantari and Cabrera, 2012).

Reproduction. Voluntary waiting period (VWP) was set to 50 d. The first occurrence of postpartum ovulation was modeled using lognormal distribution (De Vries, 2001). Cows with DIM ≥ VWP were observed for estrus and had a risk for breeding and conception. The estrus cycle length was determined from a normal distribution with an average of 21 d and a standard deviation of 4 d. Cows detected in estrus (50%) and conceiving (40%) were marked as pregnant. An 8% risk of pregnancy loss was considered from 30 days to term with an empirical distribution determining the day of occurrence. Gestation length of a cow was modeled using a normal distribution of 278 days with a standard deviation of 6 days.

Body weight. Cow-specific initial body weight (BW) came from dairy farm records or, if not available, was sampled from a triangular distribution with a minimum of 550 kg, a maximum of 1,000 kg, and a most likely value of 700 kg. A function (Korver et al., 1985) was used to simulate BW changes throughout lactation.

Deterministic Parameters

Dry matter intake. Daily dry matter intake (DMI) was calculated using NRC (2001) equation, a function of maintenance and milk production, adjusted for decreased DMI during the early lactation period.

Cow nutrient requirements

Net energy - Total net energy (NE) requirement of a cow was calculated by aggregating the requirements for maintenance (NE_m) and milk production (NE_L) based on NRC (2001) equations.

Crude protein - Total crude protein (CP) requirements were also calculated by summing up the CP for maintenance (CP_m) and for milk production (CP_L) based on equations presented in McGilliard et al. (1983).

Economic Parameters

Milk price was set to $0.35/kg of milk. The nutrients costs were set to $0.116/Mcal of NE and to $0.747/kg of CP based on Cabrera et al. (2012).

Nutritional Grouping Strategies

Cows were assigned to 2 types of groups: 1) obligated groups and 2) optional groups. Obligated groups included dry cows and fresh cows (1 to 21 DIM). Optional groups were used to test the effect of nutritional grouping on the overall income over feed costs (IOFC), nutrient excretion, and efficiency of the nutrient used by cows.

Cows were ranked and grouped based on actual CP and NE_L requirements (cluster grouping, McGilliard et al., 1983). Every month, cows were regrouped and reassigned to the same or different group based on their rank. Allocation of cows to optional groups was designed to maximize the IOFC (Cabrera et al., 2012). An effect of milk depression of 1.82 kg/day for 5 days for cows moving to a new group was included.

Diet formulations were based on a group of cows' requirements of NE_L and CP and were set at the 83rd percentile (Stallings and McGilliard, 1984), but based on actual group nutrient requirements and not on group milk production.

Analysis Performed With Stochastic and Dynamic Model

Five dairy herds were studied (Table 1) according to nutritional grouping strategies. Analyses included calculations of economic efficiency and energy and nitrogen (N) use efficiencies because of nutritional grouping. Analyses

included the effect of milk depression on the economic and nutrient use efficiency.

Table 1. Dairy herds analyzed using the stochastic dynamic model

Lactating cows, n	570	787	727	331	1,460
Herd ME305, kg/year	16,140	12,884	13,897	13,348	14,188
1st Lactation, %	43	39	39	38	45
DIM	187	178	201	208	189
21-d PR, %	18	19	19	17	18
Culling, %/year	32	37	36	35	40
Abortion, %/gestation	7	11	11	16	7
Cow BW available	no	no	yes	yes	no

Simplified Decision Support Tool

Grouping Strategies for Feeding Lactating Dairy Cattle Tool

Based on principles above described, a simplified online decision support tool has been developed, *grouping strategies for feeding lactating dairy cattle*, and it is openly available at the University of Wisconsin-Madison Dairy Management Website (http://DairyMGT.info: Tools). Briefly, users can perform herd-specific analyses after entering cow-level records. Users need to define current herd nutritional characteristics, and describe potential changes related to nutritional grouping. The tool calculates the economic difference between current and proposed situations (Cabrera et al., 2012).

Differences of Tool with Above Description

There are 2 main structural differences between the online decision support tool and the research methodology described above. The first one is related to the stochasticity. The decision support tool does not contain random elements in the calculations. The second major difference is related to dynamics. Whereas the methodology described above simulates day-by-day every cow on the herd, the decision support tool performs the analysis at one specific point in time (based on records entered by user). In consequence, the decision support tool does not perform projections and therefore should be used frequently (i.e., every month). The decision support tool demonstrates the economic value of nutritional grouping and it is better suited for initial approximated extension messages. Advantage of the decision support is its user-friendliness and the opportunity of interactivity for "what if" analyses. Also, the decision support tool counts with an additional module that can evaluate additional costs or savings beyond milk income and feed costs when performing nutritional grouping management strategies.

Analysis Performed With Online Decision Support Tool

Cow-level records of 30 Wisconsin dairy herds were analyzed using the tool. Without knowing their actual nutritional grouping strategies, the same procedure was applied at each of the herds: 1) comparisons were always between 1 group and 3 same-size groups; 2) prices were set at milk ($0.35/kg), CP ($0.3158/kg), and NE_L ($0.1174/Mcal) for all farms; 3) requirements of CP and NE_L were at the 83rd percentile for both 1 or 3 groups; and 4) average BW was set at 500 kg for primiparous and at 590 for multiparous.

■ Results and Discussion

Stochastic Model

Economic Efficiency

Economic efficiency measured as IOFC increased consistently with additional nutritional groups (Figure 1). On average and compared to 1 nutritional group, the IOFC gain ($/cow per year) was 21, 46, 57, 65, and 70 for 2, 3, 4, 5, and 6 nutritional groups, respectively. Curves in Figure 1 follow a decreasing increasing trend (law of diminishing returns) after 3 nutritional groups, indicating that there is still a gain for more than 3 nutritional groups, but the gains decrease. It is also important to notice that there is a relationship between number of groups and herd size, indicating a higher opportunity of grouping in larger herds. In all cases, more than 4 or 5 nutritional groups might be impractical, but are still provided for analyses purposes. In small herds (e.g. 331) more than 3 groups might be impractical.
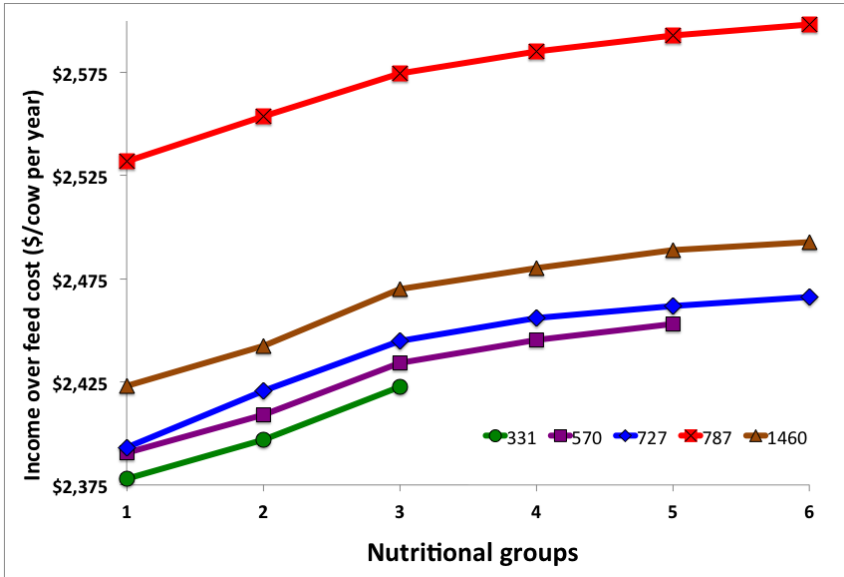
Figure 1. Economic efficiency of nutritional grouping strategies in 5 Wisconsin dairy herds (Table 1). Labels indicate the number of lactating cows on herd

Energy Efficiency

Utilization of energy measured as the percentage of energy in milk (Mcal milk) over the energy consumed in feed (Mcal consumed) increased consistently with additional nutritional groups until 4 groups (Figure 2). It continued increasing for the largest herd (1460 cows) until 6 groups and for the 727 cow herd until 5 groups. This indicates clearly that grouping strategies are herd specific and depend on herd size. On average and compared to 1 nutritional group, the efficiency of energy use increased (%) 0.18, 0.59, 0.81, 0.82, and 0.87 for 2, 3, 4, 5, and 6 nutritional groups, respectively (Figure 2). It is interesting to notice that in the largest herd (1460) there was no apparent gain from 1 to 2 groups and the gain from 2 to 3 groups was smaller than other herds. Nonetheless, this herd showed greater gains than other herds with more nutritional groups.

Nitrogen Efficiency

Utilization of N measured as percentage of N in milk (kg) over the N consumed in feed (kg) also increased consistently with additional groups (Figure 3).
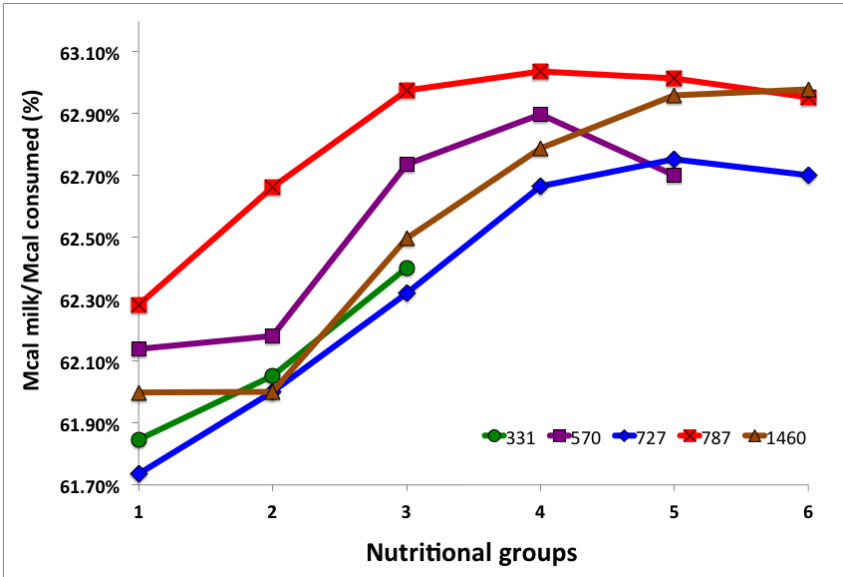
Figure 2. Energy use efficiency of nutritional grouping strategies in 5 Wisconsin dairy herds (Table 1). Labels indicate the number of lactating cows
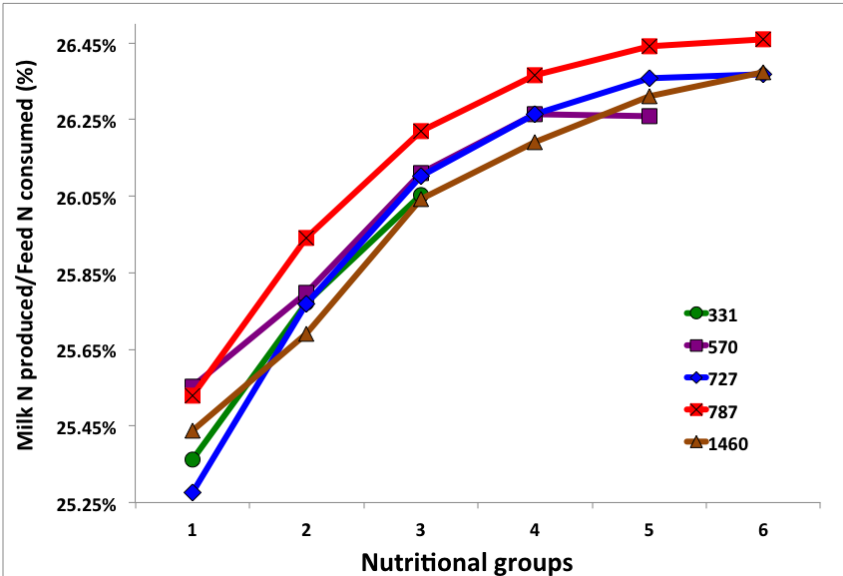

Figure 3. Nitrogen use efficiency of nutritional grouping strategies in 5 Wisconsin dairy herds (Table 1). Labels indicate the number of cows.

Differently than energy, with exception of herd 570, N efficiency continued to increase up to 6 groups (at a diminishing return). On average and compared to 1 nutritional group, N efficiency (%) was 0.36, 0.67, 0.84, 0.91, and 0.97, for 2, 3, 4, 5, and 6 nutritional groups, respectively.

Impact of Milk Depression

Milk depression because of cows being relocated to different groups, as defined in this study (1.82 kg/day milk loss for 5 days = 9.1 kg milk), had an overall economic impact that decreased IOFC between $16 (2 nutritional groups) and $23 (6 nutritional groups) (Figure 4, difference between bars) on a herd having 787 lactating cows. This strategy also had an overall N efficiency use impact that decreased the ratio milk N produced/feed N consumed between 0.05% (2 nutritional groups) and 0.13% (6 nutritional groups) (Figure 4, difference between curves).
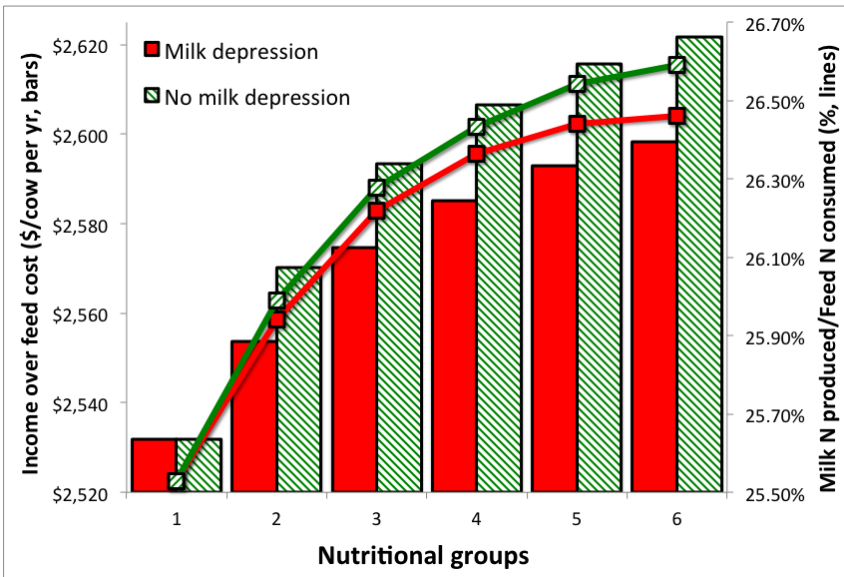

Figure 4. Economic and N use efficiency with and without considering milk depression on the herd 787 (787 lactating cows).

Considering that the IOFC gain for 2 nutritional groups without milk depression would have been $33, the impact of milk depression represents a 48% decrease in the gain just because of milk depression, a large impact. The impact of milk depression on IOFC decreased as more nutritional groups were in place. This was about 30% for 3 nutritional groups. Also, considering that the IOFC gain for 6 nutritional groups would have been $90, milk depression represents a 25% decrease in the gain, still an important impact.

Simplified Decision Support Tool Results

Evaluations of 30 Wisconsin dairy farms with online decision support tool
(http://DairyMGT.info: Tools: *Grouping strategies for feeding lactating dairy*
cattle) consistently demonstrated in all 30 herds that IOFC was greater for the
nutritional grouping strategy that included 3 nutritional groups compared with
the strategy of only 1 nutritional group (Table 2).

**Table 2. Economic nutritional grouping evaluation of 30 Wisconsin dairy
farms using the online tool *Grouping strategies for feeding lactating
dairy cattle.***

	Number lactating cows	1 nutritional group	3 same-size nutritional groups	Difference between 3 and 1 nutritional groups
	(n = 30)	------------------IOFC, $/cow per year--------------------		
Mean	788	2,311	2,707	396
Min	<200	697	1,059	161
Max	>1,000	2,967	3,285	580

The analysis indicated that farms could realize between $161 and $580/cow
per year (mean = $396) of additional IOFC by switching from no grouping to 3
same-size feeding groups using the cluster criterion for grouping. These
values represented an increase of between 7 and 52% of farm calculated
IOFC.

Performing grouping and feeding different rations to the groups could have
additional costs and possible economic losses. After assuming reasonable
costs of management, labor, and machinery and reasonable expected milk
depression (1.82 kg/day for 5 days) on those cows affected by the grouping
changes, the net return of grouping was still much greater than the no groping
option. The additional IOFC estimated in Table 1 decreased between 9 and
25% for these scenarios. Therefore, 3 same-size feeding groups was still
much more profitable in all 30 herds than the sole 1 feeding group option.

■ Conclusions

We conclude that additional nutritional grouping on lactating dairy cattle has a
positive impact on the economic and environmental efficiency of a dairy farm.
Benefits will vary largely depending on farm and market conditions, but our
conservative projection analyses indicate that a farm could expect about
$45/cow more IOFC per year, 0.59% increased energy efficiency use, and
0.31% increased N efficiency use when a farmer would decide to manage 3

nutritional groups that currently is managing only 1 nutritional group for all lactating cows. A user-friendly online decision support tool is openly available at the University of Wisconsin Dairy Management Website (htttp://DairyMGT.info) and could be an effective tool for initial demonstration and motivation to promote nutritional grouping on lactating dairy cattle.

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